

Pion spectra in Ar+Sc interactions at SPS energies*

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This contribution discusses recent results from analysis of Ar+Sc interactions recorded with the NA61/SHINE detector at six beam momenta: 13A, 19A, 30A, 40A, 75A, 150A GeV/c at the CERN SPS. Rapidity and transverse mass spectra of pions obtained with the "h-" analysis method are presented and compared to results from p+p, Be+Be and Pb+Pb collisions.

PACS numbers: PACS numbers: 25.75.-q, 25.75.Ag, 25.75.Gz, 25.75.Dw, 25.75.Nq

1. Introduction

NA61/SHINE is a fixed target spectrometer located in CERN's North Area utilizing the SPS proton, ion and hadron beams [1]. Tracking capabilities are provided by four large volume Time Projection Chambers (TPC), two of which are located in the magnetic field. The Projectile Spectator Detector (PSD) – a zero degree, modular calorimeter, is used to determine centrality of the collisions.

The aim of the experiment is to explore the QCD phase diagram (μ_B, T) by a two-dimensional scan in collision energy and system size. The yields of hadrons produced in the collisions are studied for indications of the onset of deconfinement (*kink*, *horn* and *step*) and the critical point of the phase transition (hill in event-by-event fluctuations). Recent measurements of Argon and Scandium collisions are an important step in this program. Comparison of negative pion spectra give important insight into the dynamics of ion collisions at the border of light and heavy nuclei.

* Presented at the Critical Point and Onset of Deconfinement 2016, Wrocław, Poland, May 30th - June 4th, 2016

2. h^- Method

Negatively charged pion spectra were measured using the so called "h⁻ method". It exploits the fact that $\approx 90\%$ of negative hadrons produced in the SPS energy range are π^- mesons. The small ($\approx 10\%$) contribution of other particles (K^-, \bar{p}) was subtracted from negative pion spectra using simulations with the EPOS-1.99 model [2]. The latter was tested on proton-proton data and showed only small discrepancies in the ratio K^-/π^- (K^- are the main contribution to the correction)[3].

3. Data analysis

The events recorded by the NA61/SHINE spectrometer were selected for data quality and centrality of the collisions. Centrality classes were determined using the PSD, located most downstream on the beam line. It measures predominantly the projectile spectator forward energy E_F of the non-interacting nucleons of the beam nucleus. The distribution of E_F was used to define and select event classes corresponding to the collision centrality.

Corrections of the raw data was based on EPOS-1.99 [2] (version CRMC 1.5.3.) model simulation of hadron interactions and the GEANT-3.2 code for particle transport and detector simulation (see [4]). Centrality classes in the model calculations were selected by the number of forward spectator nucleons.

Results presented in the plots are shown only with statistical uncertainties. These come from two sources: the experimental data and the simulation based corrections. The contribution of the latter is insignificant ($< 0.1\%$). Based on the previous analysis of Be+Be[5] and p+p[4] reactions, we estimate systematic errors at a level of 5%-10%.

4. Rapidity and Transverse Momentum Spectra

Results, corrected for acceptance and background, were obtained for the 5% most central Ar+Sc interactions at beam energies of 19A, 30A, 40A, 75A and 150A GeV/c. These are compared to measurements from inelastic p+p [4] and the 5% most central Be+Be collisions [5] from NA61/SHINE as well as from central (5 %or 7%) Pb+Pb collisions from NA49 [6, 7].

Preliminary results on double differential negatively charged pion spectra are presented in Fig.1 for beam energies of 19A, 40A, and 150A GeV/c. They cover the full forward rapidity hemisphere. In order to obtain rapidity distributions $\frac{dn}{dy}$, the data was extrapolated beyond the detector acceptance. The extrapolation in the direction of p_T from the acceptance edge to the $p_T = 3.0$ GeV/c was performed with an exponential dependence fitted

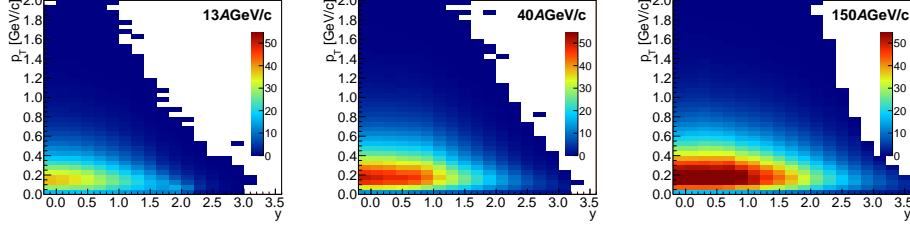


Figure 1. Measurements of the double differential spectra $\left(\frac{dn^2}{dy dp_T}\right)$ of negatively charged pions in central Ar+Sc collisions.

in the measured region.

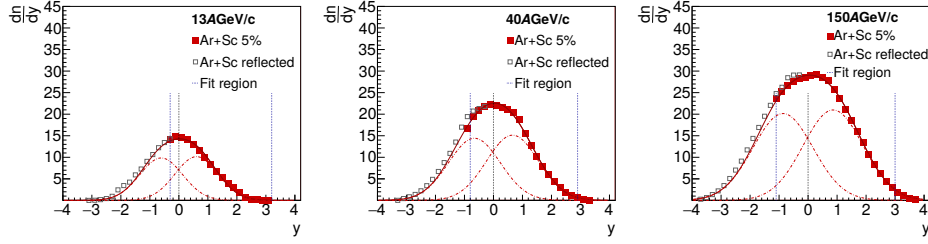


Figure 2. Rapidity spectra of negatively charged pions in central Ar+Sc collisions.

Resulting rapidity spectra (see Fig. 2) are asymmetric with respect to mid-rapidity. Thus they were fitted with two Gaussian functions, placed symmetrically around mid-rapidity, with different amplitudes:

$$f_1 = \frac{A_0 A_{rel}}{\sigma_0 \sqrt{2\pi}} \exp\left(-\frac{(y - y_0)^2}{2\sigma_0^2}\right), \quad f_2 = \frac{A_0}{\sigma_0 \sqrt{2\pi}} \exp\left(-\frac{(y + y_0)^2}{2\sigma_0^2}\right) \quad (1)$$

$$f_{fit} = f_1 + f_2, \quad \sigma = \sqrt{\sigma_0^2 + y_0^2}$$

Two opposing effects influence the asymmetry of the spectra: the asymmetry of the system (^{40}Ar projectile on ^{45}Sc target) and the centrality selection based on projectile spectators. The effect of the projectile-spectator asymmetry ($A_{rel} > 1$) is overcome by the larger effect introduced by centrality selection ($A_{rel} < 1$) (see Fig. 3 left). The width σ of the rapidity distributions shows monotonic behavior with increasing energy (see Fig 3 right).

However, non-monotonic behavior is observed for the dependence of σ on the system size (Fig. 3 right):

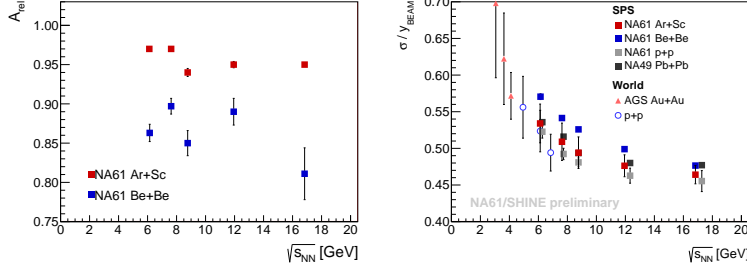


Figure 3. Results of fits of the rapidity distributions with two Gaussians Eq. 1: relative amplitude (left) and width (right). Measurements for Ar+Sc are shown and compared to other systems.

$$\frac{\sigma_y(p+p)}{y_{beam}} < \frac{\sigma_y(Ar+Sc)}{y_{beam}} \approx \frac{\sigma_y(Pb+Pb)}{y_{beam}} < \frac{\sigma_y(Be+Be)}{y_{beam}}$$

Results for p+p collisions, however, are not yet corrected for isospin effects.

In order to investigate the system size dependence of the shape of the π^- rapidity spectra $\frac{dn}{dy}$ the results from central nucleus-nucleus interactions are divided by those from inelastic p+p interactions. The spectra were normalized to the same integral in $y \in (0.0, 0.5)$ before division.

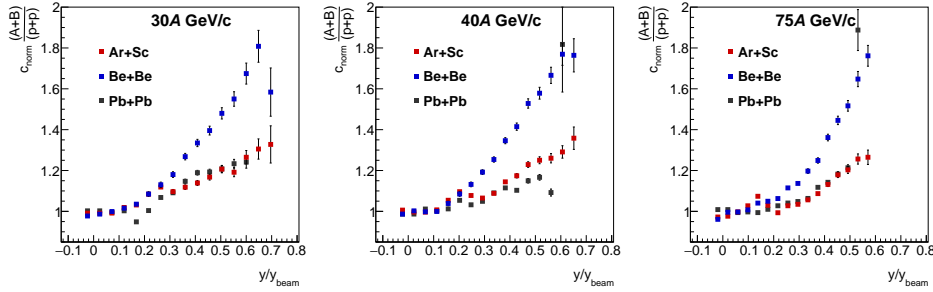


Figure 4. Ratio of $\frac{dn}{dy}$ spectra of π^- produced in central nucleus-nucleus collisions to that from inelastic p+p reactions.

From the results plotted in Fig 4 one observes that the spectrum shape of π^- produced in Ar+Sc interactions is almost identical to the one from Pb+Pb, while data for Be+Be drift away significantly.

5. Transverse mass distribution

Transverse mass spectra of π^- for Ar+Sc interactions, shown in Fig.5, show deviations from the exponential behaviour seen in p+p collisions. These

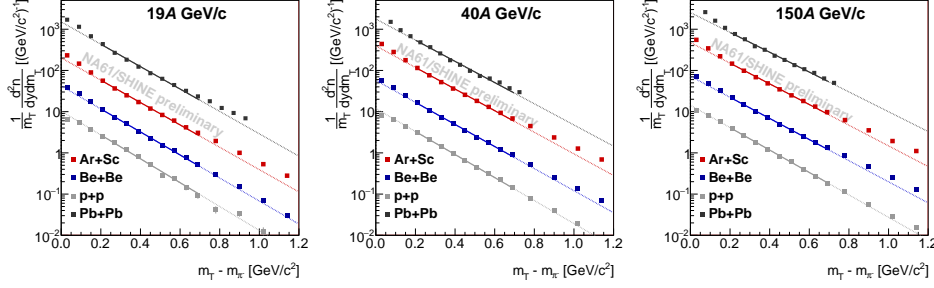


Figure 5. m_T spectra of π^- produced in Ar+Sc, as well as other central nucleus-nucleus interactions. Lines depict results of exponential fits in $(m_T - m_{\pi^-}) \in (0.2, 0.7)$.

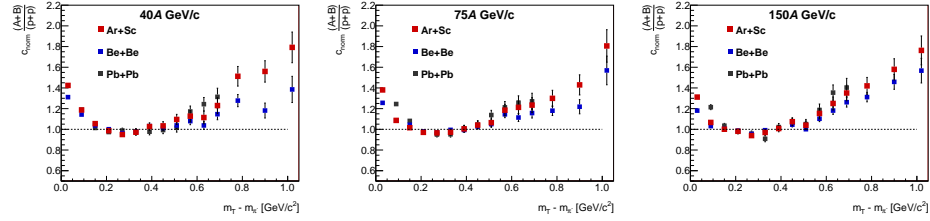


Figure 6. m_T spectra of π^- in nucleus-nucleus collisions divided by the p+p data. The spectra were normalized to the integral in $(m_T - m_{\pi^-}) \in (0.2, 0.7)$ before dividing.

indicate effects of radial flow as seen for Pb+Pb and Be+Be interactions.

Another observation on transverse mass spectra is that the deviation from the p+p data at high m_T is larger for heavier nuclei, while there is no observable dependence on collision energy (see Fig. 6).

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